3rd Semester and Master's Thesis Ideas 2012

M.Sc. in Civil and Structural Engineering

Clausen, Johan

Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

M.Sc. in Civil and Structural Engineering:

3rd Semester and Master's Thesis Ideas 2012

Edited by Johan Clausen

ISSN 1901-7308
DCE Latest News No. 31

AALBORG UNIVERSITY
Department of Civil Engineering

Aalborg University
Department of Civil Engineering
School of Civil Engineering

DCE Latest News No. 31

M.Sc. in Civil and Structural Engineering: 3rd Semester and Master's Thesis Ideas 2012

Edited by

Johan Clausen

May 2012

Scientific Publications at the Department of Civil Engineering

Technical Reports are published for timely dissemination of research results and scientific work carried out at the Department of Civil Engineering (DCE) at Aalborg University. This medium allows publication of more detailed explanations and results than typically allowed in scientific journals.

Technical Memoranda are produced to enable the preliminary dissemination of scientific work by the personnel of the DCE where such release is deemed to be appropriate. Documents of this kind may be incomplete or temporary versions of papers—or part of continuing work. This should be kept in mind when references are given to publications of this kind.

Contract Reports are produced to report scientific work carried out under contract. Publications of this kind contain confidential matter and are reserved for the sponsors and the DCE. Therefore, Contract Reports are generally not available for public circulation.

Lecture Notes contain material produced by the lecturers at the DCE for educational purposes. This may be scientific notes, lecture books, example problems or manuals for laboratory work, or computer programs developed at the DCE.

Theses are monograms or collections of papers published to report the scientific work carried out at the DCE to obtain a degree as either PhD or Doctor of Technology. The thesis is publicly available after the defence of the degree.

Latest News is published to enable rapid communication of information about scientific work carried out at the DCE. This includes the status of research projects, developments in the laboratories, information about collaborative work and recent research results.

Published 2012 by
Aalborg University
Department of Civil Engineering
Sohngaardsholmsvej 57,
DK-9000 Aalborg, Denmark

Printed in Denmark at Aalborg University

ISSN 1901-7308
DCE Latest News No. 31

M.Sc. in Civil and Structural Engineering: 3rd Semester and Master Projects Ideas

The following pages contain a list of project ideas proposed by the scientific staff at the Department of Civil Engineering, Aalborg University, and a number of companies. Most of the project ideas in this catalogue may form the basis for long and short master projects as well as regular 3rd semester projects at the M.Sc. programme in Civil and Structural Engineering.

Each project description provides a brief overview of the purpose as well as the main activities. Further, a weighting between theoretical analysis, experimental work and computer modelling has been proposed. Usually, this weighting can be changed slightly in accordance with the wishes of the students. The contact persons listed will act as primary supervisors. Questions regarding details about each proposed project should be asked to these persons. The contact details can be found via a person search on the university home page. Further, other ideas for projects may be discussed with a potential supervisor.

Most private engineering companies have a homepage on which they state that they would like to collaborate with students on a master project. Examples are:

- Dong, http://www.dongenergy.com/da/job/studerende/specialekonkurrence/pages/wind_power.aspx
- Cowi, http://www.cowi.dk/menu/jobs/ungicowi/praktikspecialeogstudiejob/byggeri/Pages/byggeriogdriftforstuderende.aspx
- Rambøll, http://www.student.ramboll.dk/projekt%20eller%20speciale
- Grontmij, http://www.grontmij.dk/DK/job-karriere/Studerende/Projekt/Pages/default.aspx

The preferred group size for master projects is two to four students. In the interest of students as well as supervisors, single-student projects are generally not recommended. In a short 3rd semester project the minimum group size is three students.

At the third master semester the students have the option of doing a company stay. It is important to notice that this is not a traditional internship, but rather a short third semester project carried out in cooperation with a private or public company. An example of a successful subject for such a company stay is also given in this catalogue in the last page.

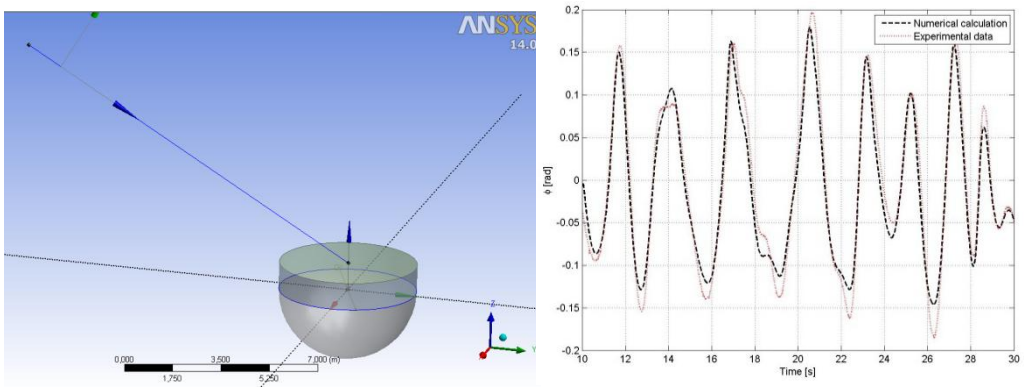
As a final remark, a signed project plan must be handed to the head of the School of Engineering and Science at latest one month after the initiation of the project. This

project plan must contain information about the project, in particular regarding the educational goals of the project. These must be defined in accordance with the Master Curriculum (danish: Studieordningen) for the M.Sc. Programme in Civil and Structural Engineering at the School of Engineering and Science, Aalborg University. The curriculum can be found at the Study Board of Civil Engineering homepage at http://www.ses.aau.dk/digitalAssets/14/14964_msc_k_250610.pdf. A document template for the project plan is available at the homepage of the School of Engineering and Science at http://www.ses.aau.dk/digitalAssets/32/32582_projektplan_word.doc (Danish version) and http://www.en.ses.aau.dk/digitalAssets/32/32588_project-plan_word.doc (English version)

Aalborg, May 3, 2012 Johan Clausen, *semester coordinator*

Structural Analysis of Wave Energy Converters

Purpose: The cost of energy from renewable resources in general, and from waves in particular, is a critical factor in order to compete with other forms of power generation such as fossil-fuelled power generation. The goal within this study is to reduce the capital costs, operating and maintenance costs and risks by optimizing the structural design of wave energy converters (WECs).



Similar to floating offshore structures, WECs are subjected to high fatigue loadings due to the harsh environment in the sea during normal operation and extreme events. To estimate the fatigue damage of relevant critical components of a WEC, time-domain simulations are required to obtain the loadings on the structure. Thus, the first part of the project consists of finding the dynamic response of a floating WEC based on linear fluid-structure interaction. A thorough use of the software tool ANSYS AQWA/WORKBENCH is planned in order to estimate the hydrodynamic loads for a given set of wave states. Long-term stresses are obtained by combining the short-term time simulation results (first part) with the occurrence probability of each sea state. Based on the long-term stress distribution the fatigue damage of the critical sections is obtained by using the SN-Miner Palmgren approach according to the DNV-RP-C203/205 standards. Finally, a sensitivity study of the different simplified control strategies on the fatigue damage is envisaged.

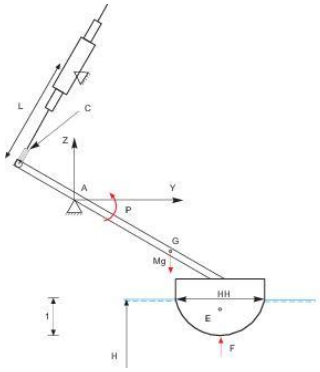
Main activities: The project consists of the following sub tasks:

- Numerical modelling of a floating wave energy converter with ANSYS AQWA (Students choose among three WEC devices), validation with experimental time series (already available).
- Structural analysis of critical components by means of fatigue lifetime analysis using FEM tools.
- Sensitivity analysis on the fatigue damage by introducing a power take-off system i.e. feedback force.

Contact persons: Andrew Zurkinden, Jens-Peter Kofoed
Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒

Prediction of dynamic response of Wave Energy Converters

Purpose: Currently, a number of wave energy converters are being analysed by means of numerical models in order to predict the electrical power generation under given wave conditions. The goal within this project is to develop numerical models for motion analysis of marine structures with a special emphasis on wave energy structures (WES).



The overall goal of a numerical model is to accurately describe the dynamics of a floating offshore WES for a given wave state by taking into account the loadings from the hydrodynamics, power take-off and mooring forces. A common characteristic of such models is the assumption of linear fluid-structure interaction and the linearization of the equation of motion in the time-domain. The first part of this project consists of modelling the linear hydrodynamic behaviour of floating offshore structures in the frequency domain. In a next step a solver for the equations of motion is built in MatLab and applied to several WEC´s. The student will get familiar in going back and forth between the time- and frequency-domain representations of the problem. Finally, the integration of nonlinear effects such as nonlinear hydrostatic restoring forces or viscous damping forces are included in the analysis.

Main activities: The project consists of the following sub tasks:

- Theory study about numerical analysis of floating offshore structures, analysing frequency domain models, calculate the hydrodynamic loads by means of FEM/BEM software (ANSYS AQWA/WORKBENCH).
- Develop a solver for the equation of motion and estimate the power production under the assumption of linear fluid-structure interaction. Compare the numerical results with experimental data (already available).
- Improve your solver by taking into account non-linear effects such as non-linear hydrostatic restoring forces, drag forces and compare the results with the linear case.

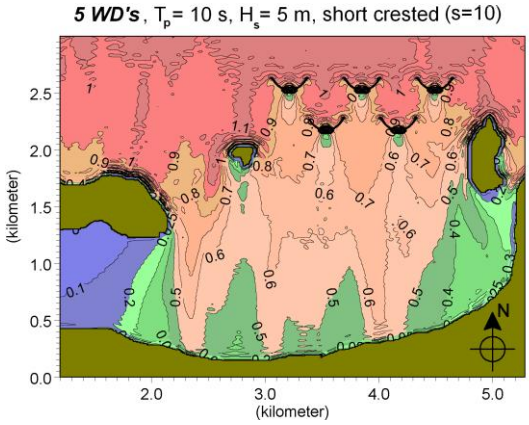
Contact persons: Andrew Zurkinden, Morten Kramer
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

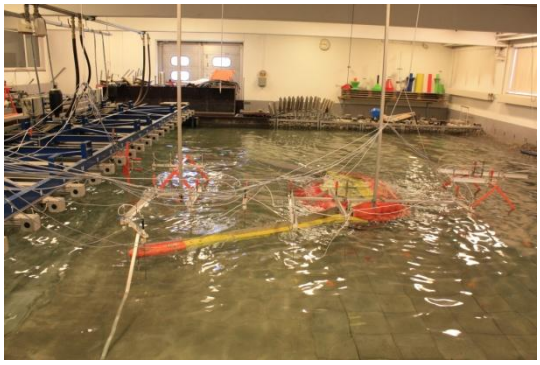
Wave energy converters for use in coastal protection

Purpose: The purpose is to adopt wave energy converters for mitigation of flooding and coastal erosion hazard in the context of increasing storminess and sea level rise. A proposal is to place wave energy converters close to the shoreline for contemporary attenuating wave attacks and thereby produce a secondary benefit.

Physical model tests on a single Wave Dragon wave energy converter have already been performed at AAU in scale 1:50 to measure the wave height reduction behind the device. Measurements from the tests have been used in the calibration of a numerical wave propagation model.

However, additional tests are still needed to perform more detailed analysis on the wave scattering from the devices. Moreover, numerical simulations should be performed to evaluate the influence from the Wave Dragons on the sediment transport in a specific bathymetry.





Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Experimental and/or numerical modelling of wave scattering from floating devices positioned in different arrays
- Case study on the influence on wave climate at specific site
- Case study on the influence on sediment transport at specific site
- Theoretical assessment of wave transmission through a wave energy converter

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen, Thomas Ruby Bentzen

Theory: ☒☐☐ Experimental work: ☒☒☐ Computer modelling: ☒☒☐

Run-Up on Piles in Irregular Waves

Purpose: Run-up can cause significant loads to entrance platforms at offshore wind turbines. In the Danish wind turbine park Horns Reef 1 several platforms have been damaged due to that issue. Therefore the offshore wind industry is very interested in run-up and the present project can be carried out in cooperation with DONG Energy who has expressed high interests in such project.

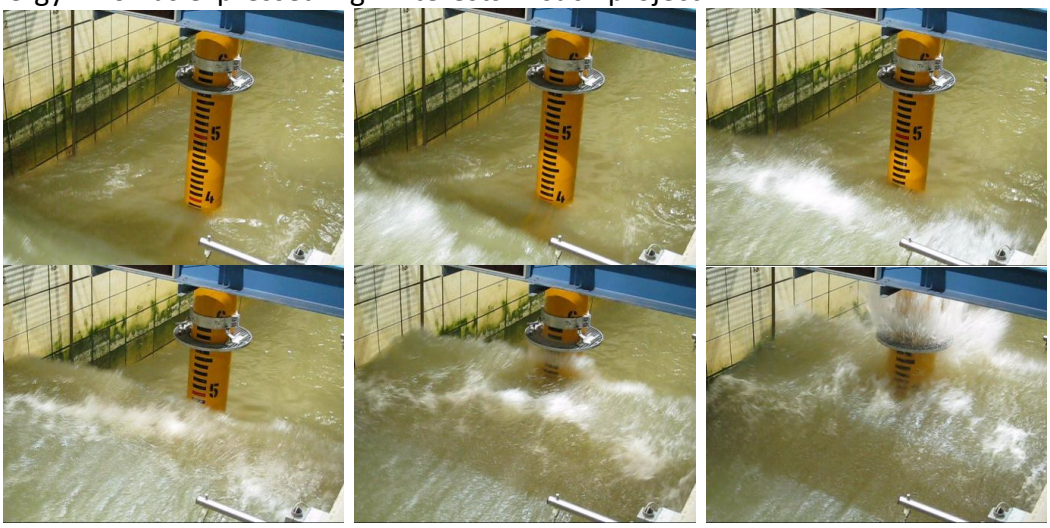


Fig. 1: Large scale testing of loads on wind turbine access platforms.

A model for run-up in irregular waves is wanted and thus accurate estimations of the kinematics of irregular breaking or nearly breaking waves is needed. For regular waves the stream function theory is well accepted and used. However, for irregular waves a local Fourier approximation exists, leading to an approximation of the stream function in irregular waves. This makes it possible to calculate wave kinematics in waves that are not symmetrical around the wave crest. In the present project such method can be implemented and tested against large scale run-up tests.

Main activities:

- Look at newly performed model tests to quantify importance of wave shape on run-up on piles and loads on secondary structures
- Implementation of Local Fourier approximation code in MatLab or other programming language (good programming skills needed)
- Application of method to newly performed large scale tests. Additional verification tests can be performed in small scale if needed.

Contact person: Thomas Lykke Andersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

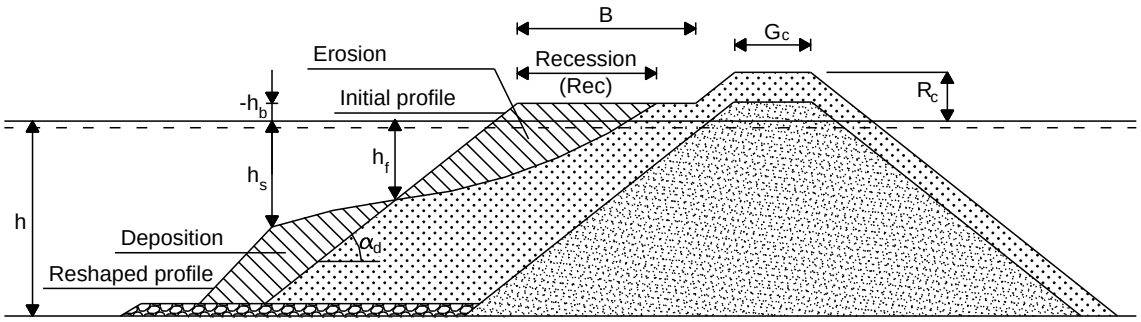
Projects on Breakwater Design

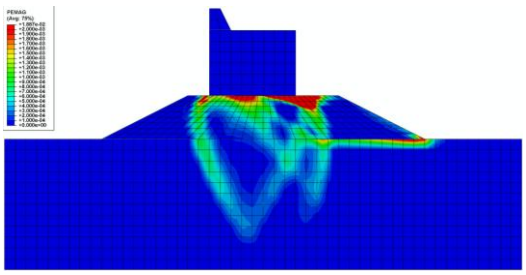
Purpose: A number of different projects are available within design of caisson or rubble mound breakwaters are available depending on main interest area.

The main activity would for most projects be laboratory model tests but also projects involving detailed computer modelling are available.

Examples of topics:

- Overtopping and stability for rubble mound breakwaters exposed to long waves or combinations of long waves and short waves (swells and wind waves).
- Stability of crown walls
- Stability of caisson breakwaters exposed to impulsive loading

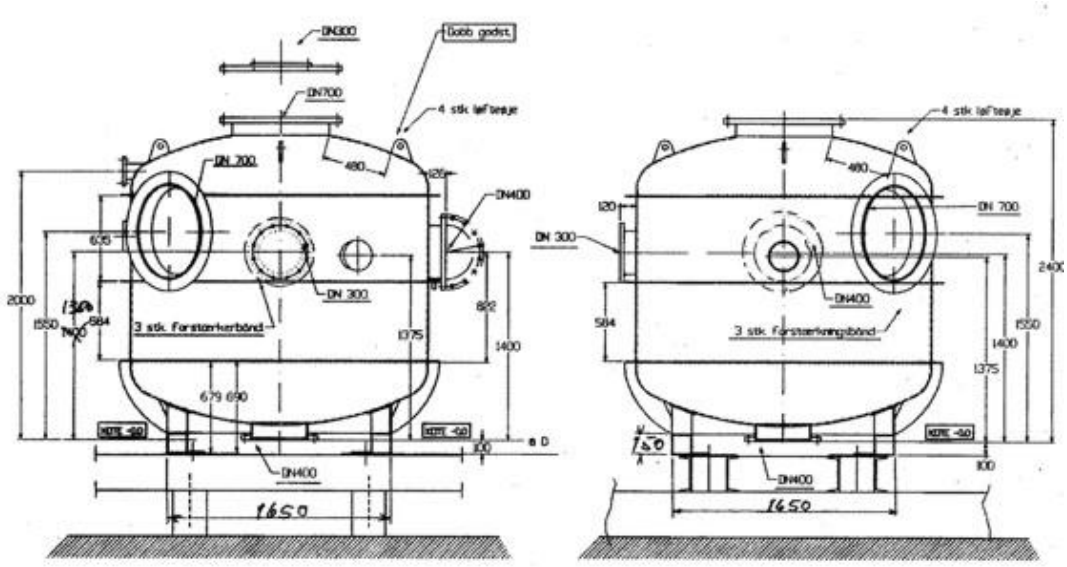




Contact person: Thomas Lykke Andersen

Bøttefundamentets styrke- og deformationsegenskaber ved cyklisk belastning

Purpose: De kræfter der virker på vindmøller, transient og cykliske i natur, giver anledning til elastiske oscillationer og muligvis til liquefaction af sandet inde i bøtten. Sådan sand liquefaction vil sandsynligvis føre til fuldstændige bæreevnesvigt, hvorfor liquefaction skal undgås.



Main activities: Forholdene, der kan føre til sådanne tilstande, skal undersøges og fastlægges ved eksperimenter. En forsøgstank indeholdende faciliteter til udlejring af jorden samt mulighed for statisk og transient og cyklisk belastning er udviklet i dette forår ved laboratoriet for fundering, Aalborg Universitet, se figuren. Tanken ønskes gennem dette projekt at blive gjort fuld operationel. Tankens belastningssystem er opbygget således, at det kan benyttes til cykliske udmattelsesforsøg. Herved kan risikoen for liquefaction undersøges:

Resultaterne af disse forsøg sammenholdes med resultaterne fra de statiske forsøg. Herved kan det evalueres, om den varierende belastning har indflydelse på fundamentets bæreevne, stivhed samt plastiske deformationer.
Den elastiske opførsel under cyklisk belastning er vigtig for interaktionen med tårnet, og dette skal kortlægges ved hjælp af eksperimenter, analyse og beregning på baggrund af elasticitetsteori udfra de udførte forsøg noget til sidst.

Contact person: Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Bøttefundamentets styrke- og deformationsegenskaber ved installation i ler

Purpose: 3-D numerisk simulering af forskellige typer af bøttefundamenter installeret i ler foretages. Deres anvendelighed til offshore vindmøller undersøges med henblik på forståelse af deres opførsel under normale og ekstreme laster når den funderes i ler.

Main activities: Resultater fra en række modelforsøg (fra afsluttet afgangsprojekt) skal simuleres numerisk og sammenlignes med resultater fra analytiske modeller. I de numeriske simuleringer vil der blive arbejdet med en avanceret konstitutiv model for jorden, Single Hardening modellen, og det tilsigtes at jord/struktur behandles så realistisk som muligt. Denne model er implementeret i det kommercielle finite element program 3D PLAXIS som eksternt defineret materialemodel. Materialeparametre findes fra triaksialforsøg udført på jordprøver fra de relevante offshore lokaliteter og fra kalibrerede CPT-forsøg udført ved siden af borehullerne.

De simulerede bøttefundamentforsøg er de ovenfor beskrevne modelforsøg og de forsøg. Disse inkluderer udrænede forsøg, i hvilke bøtterne er påvirket af moment, horisontale og vertikale kræfter. De numeriske analyser er i stand til at simulere ændringen i størrelse og form af brudfladen i H-M/D planet, svarende til de eksperimentelle observationer.

Contact person: Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Bender elements for the measurement of soil stiffness

Purpose: Using Bender elements to determine the dynamic elastic shear modulus Gmax, for soils.

The measurement of soil stiffness is of great importance to geotechnical design. Especially for analysing and designing constructions such as wind turbines the soil stiffness is a key-parameter.

Resent research have provided dynamic methods for the measurement of soil stiffness at very small strains using piezo-ceramic plates called bender elements.

Main activities: The project can include:

- Getting to know bender elements
- Gathering and analysis of current design material
- Determination of focus areas
- Laboratory tests and theoretical assessment
- Computational modelling
- Design model creation.

Part of the project may be carried out together with geotechnical firms taking soil samples and making input for actual design problems.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

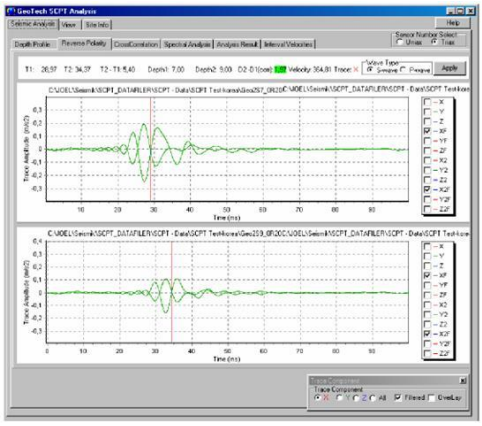
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐

SCPT - Seismic CPT

Purpose: For onshore and offshore constructions there is a growing need for analysing and determination of the elastic soil parameters.

With the seismic CPT adapter mounted on the CPT probe it is possible to carry out CPT and seismic test during the same penetration.

Best practice is needed to be carried out.



Main activities: The project is open with concern to the problem to be analysed. However the focus is on field testing. The project may include:

- Getting to know SCPT – seismic CPT
- Gathering and analysis of current design material
- Determination of focus areas
- Field tests
- Theoretical assessment
- Computational modelling of SCPT

The project can include experimental field testing on different locations in Denmark togheter with geotechnical engineering firms.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☐☐

Light Weight Deflectometer

Purpose: The Light Weight Deflectometer offers measuring of the bearing capacity for subsoil and foundation layers directly in the field.

Currently the equipment used is isotope measuring using radioactive sources with is not especially environmental friendly and safe. The LWD gives at direct output for the soil stiffness, however no systematic use for design and analysing have been setup.

Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- Getting to know Light Weight Deflectometer
- Gathering and analysis of current design material
- Determination of focus areas
- Field and laboratory Tests
- Theoretical assessment
- Design model creation / best practise.

The project may be carried out as engineering practice, and it may be possible to perform experimental tests together with Grontmij/Pavement who have introduced the equipment on the Danish market.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☐☐

Improved FEM-modeling of non-associated plasticity

Purpose: The most common material model for soils is the Mohr-Coulomb model where the soil strength is controlled by the cohesion strength and the friction angle. The deformation during plastic flow is controlled by the dilation angle. When the model is associated, i.e. friction angle = dilation angle reliable calculation methods are abundant both in the elasto-plastic as well as the rigid-plastic case. Experimental observations, however, predicts that the dilation angle should be much lower (often ~30°) than the friction angle. Unfortunately this causes a lot of computational problems. Random errors seem to occur and simulations break down.

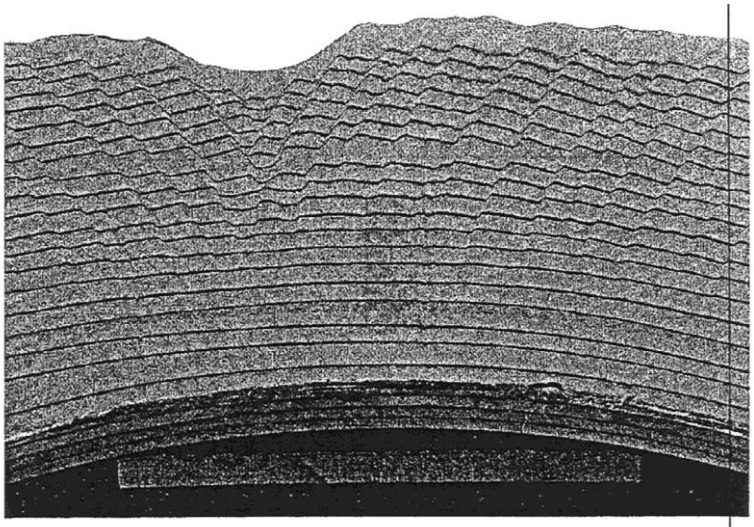


Fig. 8.2 Crestal faults over arch of uniform curvature, simulated in a sand box (Mandl, 1984).

In this project the goal is to examine how we should model non-associated soil behaviour with the finite element method. The different result of different methods could be quantified using simple benchmark calculations, e.g. a surface footing or a sheet pile wall. This project will involve a considerable amount of MatLab-programming.

Examples of main activities:

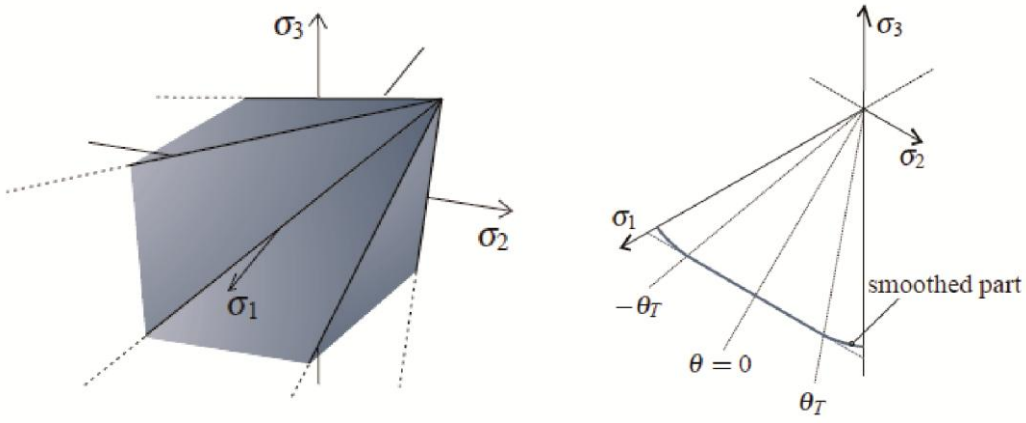
- What are the symptoms of non-associated problems? A computational and literature review.
- What do the commercial codes do (e.g. Abaqus, Plaxis, Ansys)?
- Do we have other methods of remediating the problem?
- Quantification of different results with different methods using own MatLab code

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Implementation of a plasticity model into the finite element method 1: Rounded Mohr-Coulomb

Purpose: The most often used material model for geotechnical materials is the Mohr-Coulomb material model. For calculation involving more than very simple geometries the finite element method is used for obtaining the solutions to the arising boundary value problems (i.e. load-displacement curves, bearing capacities, etc.). Originally the corners and the apex of the Mohr-Coulomb yield surface caused problems in the numerical implementation, so an approximate yield surface woth smoothed, or rounded, corners were used. Today methods for implementing the corners explicitly exist, but the use of the rounded surfaces is still widespread. The implications of using these approximations, however, are not documented in literature.



Main activities: Different models for smoothing the Mohr-Coulomb model should be implemented, and maybe also as a user programmable material in Abaqus. Then the implications of using these approximate models should be quantified and compared to the exact Mohr-Coulomb material model. Both with respect to accuracy, computation time and number of iterations. The approximate models may perform better than the exact model in some parameters and poorer in others.

An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Implementation of a plasticity model into the finite element method 2: Unified Strength Theory

Purpose: In geotechnical engineering the most widely used material model is the Mohr-Coulomb model. When the Mohr-Coulomb yield surfaces is visualised in principal stress space it consists of six planes making up an irregular pyramid with an apex and six corner lines. A characteristic of the Mohr-Coulomb model is that the intermediate principal stress does not influence the material strength, whereas true triaxial tests show that the intermediate principal stress do influence the material strength. This is the reason for the rule of thumb that the plane friction angle is 10% higher than the triaxial one. A simple remedy for this deficiency is to introduce an extra corner in the Mohr-Coulomb model. This model is known as the Unified Strength Theory. As of yet the literature have not reported any stress update schemes for this model for use with the finite element method. The challenge in such an implementation would be to include the effect of the many corners of the yield surface. This can be achieved with a recently published method on Mohr-Coulomb plasticity.

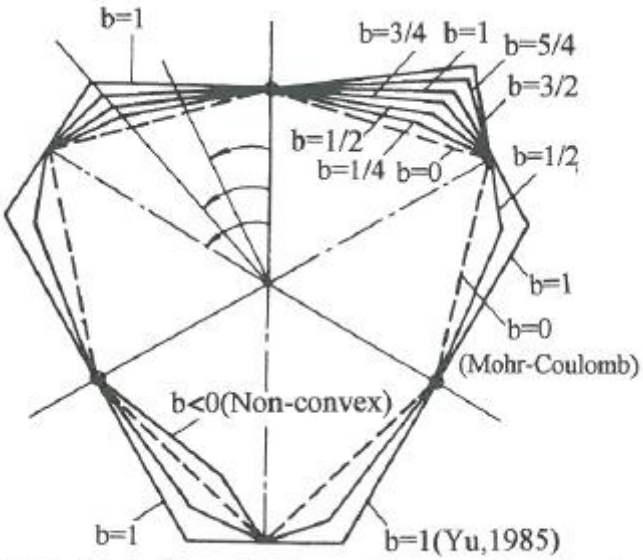


Fig. 7.7. Limit loci of the unified strength theory on the deviatoric plane

Main activities: The main activity of the project would be to implement the Unified Strength Theory in a return mapping stress update scheme. When implemented, the effect of the intermediate stress on geotechnical problems can be quantified, for example the bearing capacity of footings.

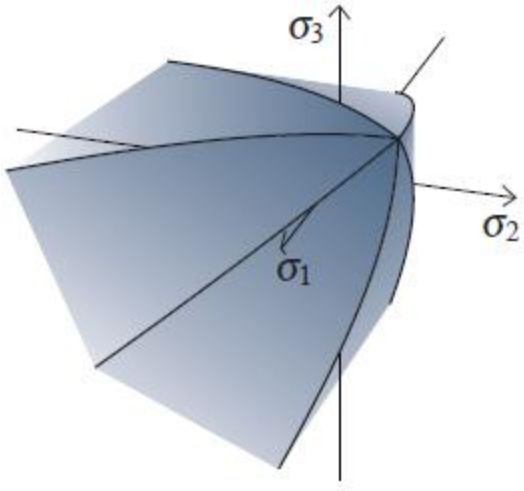
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Implementation of a plasticity model into the finite element method 3: Hoek-Brown with hardening

Purpose: The strength of rock materials is, like soils, dependent on the hydrostatic pressure. For this reason the Mohr-Coulomb model was often used to model rock masses in numerical applications. But a better material model for rock masses is the Hoek-Brown model which resembles the Mohr-Coulomb yield surface with curved edges. When a rock mass is subjected to loading, the constituents will begin to crack as stresses rise. If the influence of these cracks is significant the overall, or 'average', response of the rock mass seems to be softening, i.e. a transition from a peak strength to a residual strength. This, in turn, means that the often adopted assumption of perfect plasticity leads to poor results. A more realistic response can be found if hardening/softening plasticity is used with the Hoek-Brown model. This has a significant impact on the results when simulating certain problems in mining and tunnelling, i.e. cavities in rock masses.



Main activities: The main activity of the project would be to implement a hardening into the Hoek-Brown material model in a return mapping stress update scheme. When implemented, the effect of the hardening/softening behaviour on relevant tunnelling and mining problems can be quantified.

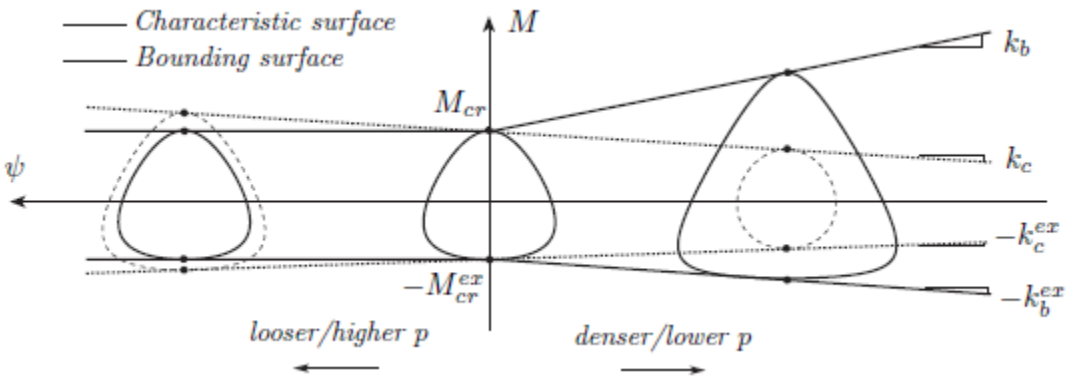
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Implementation of a plasticity model into the finite element method 4: A two-surface model for cyclic loading on sand

Purpose: For strength calculations the Mohr-Coulomb criterion is often a sufficient material model for soils. If a more precise calculation of the deformation is needed then the simple linearly elastic – perfectly plastic Mohr-Coulomb model is not adequate. This is especially true if the loading is not monotonic or even cyclic. Offshore structures are subjected to time varying loads from wind and waves which means that their foundation will experience cyclic loading. At the same time the allowable deformation is small which means that it is often this criterion rather than the soil strength that governs the foundation design. For these reasons many advanced material models for soils have been developed. If such an advanced model is to be used in practical calculations it must be implemented in a numerical method, e.g. the finite element method. Here the most efficient type of implementation is the so-called 'return mapping scheme', based on implicit integration



Main activities: The main activity of the project would be to implement a specific material model into a finite element program, which would make it possible to simulate soil structures with cyclic loading.

An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Advanced probabilistic geotechnical site assessment for offshore wind farms

Purpose: Ved opførelse af store vindmølleparker til havs udgør funderingen ikke kun en betragtelig del at anlægsudgiften 25 - 35%, men er også den del af projektet, der indeholder de største usikkerheder. For at reducere disse usikkerheder foretages et omfattende geotekniske undersøgelsesprogram, hvilket kræver en stor investering tidligt i projektforløbet. Kravet til minimering af fundamenternes deformationer gør, at det altid er anvendelsesgrænsetilstanden, der bliver dimensionsgivende, dvs. at de elastiske parametre styrer designet. Ved in-situ forsøgene bestemmes de plastiske materialeparametre, der anvendes til brudanalyse, med stor nøjagtighed, mens de elastiske parametre bestemmes med stor usikkerhed. Der er derfor i dag en konflikt mellem de parametre, der driver designet, og det man får ud af de udførte in-situ forsøg. Fokuset er i dag forkert og bør drejes mod en bedre bestemmelse af de elastiske parametre. Dette projekt fokuserer på at udvikle en in-situ test metode, der sikre bedre bestemmelse af de elastiske designparametre. Ideen er at udvikle en "intelligent sandsynlighedsbaseret teststrategi", der kombinerer informationen, som er indhentet ved seismiske undersøgelser, med in-situ forsøg i form af "Seismic Cone Penetration Test". Herved kan de elastiske parametre fastlægges med stor nøjagtighed. Dette vil resultere i mere økonomiske funderingsløsninger idet de elastiske parametre i dag fastlægges alt for konservativt - dermed overdimensionerede fundamenter. Samtidigt forventes den nye teststrategi, at bidrage til en reduktion af det nødvendige antal in-situ målinger, hvorved den samlede omkostning til fundering af havbaserede vindmøller kan reduceres markant.

Main activities: Med projektets mål for øje vil forskningen fokusere på følgende:

- Udvikle og teste SCPTu målemetoder.
- Formulerer en metode til tolkning af SCPTu forsøgene. Tolkningen skal sikre pålidelig fastsættelse af både de elastiske og plastiske materialeparametre.
- Udvikle en metode der kan beskrives de målte parametre som stokastiske variabler og fastlægge variationen med dybden.
- Tilvejebringe tilstrækkeligt statistisk grundlag for at kunne udtale sig om variationen af materiale- parametre i horisontal retning.
- Formulering og opstilling af den sandsynlighedsbaserede teststrategi.

Dette projekt kan også gennemføres i relation til motorvejsbyggeri hvor samarbejdspartnerne vil være Vejdirektoratet.

Contact person: Lars Bo Ibsen

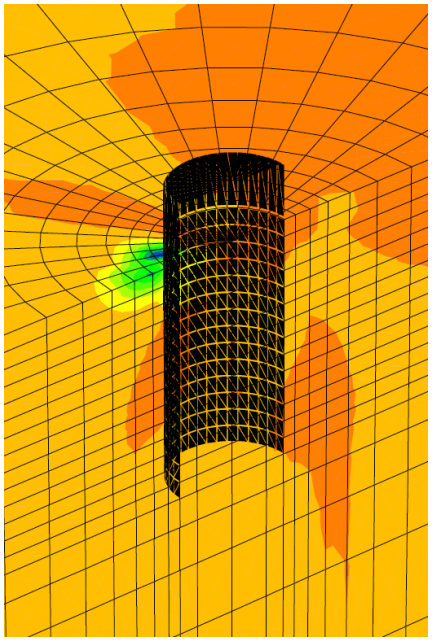
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Offshore Wind Turbine Foundations: Numerical evaluation of *p-y* and *p-Q* curves for piles in sand

A project in cooperation with

DONG energy

Purpose: The interactions between soil and laterally loaded piles are typically accounted for by use of *p-y* curves. A *p-y* curve defines the relationship *p*(*y*) between the soil resistance *p* arising from the non-uniform stress field surrounding the pile mobilised in response to the lateral pile displacement *y*, at any point along the pile. The *p-y* curves adopt the Winkler approach by uncoupling the response of various layers in the soil and can therefore easily include effects of non-linearity, soil layering and other soil properties.



Currently, *p-y* curves represent the state-of-the-art for design of monopiles in the offshore wind industry. However, the currently used p-y curves are clearly inadequate. Firstly, the current stiffness-formulation does not include diameter effects. This is of great importance since pile stiffness for often becomes the primary design driver for offshore wind turbine foundations. Secondly, the resistance of the pile toe is not considered in the current *p-y* methodology. Simple analytical considerations indicate that the ultimate moment resistance of a stiff monopile may increase by 25% if the pile toe resistance is included. Thus, the main emphasis of this project is to numerically evaluate diameter effects of p-y stiffness and evaluate the pile toe resistance in terms of *p-Q* curves.

Main activities:

- Develop a 3D finite element model of a monopile in PLAXIS (or ABAQUS).
- Calibrate constitutive behaviour to simulate Aalborg University Sand no. 1.
- Verify model by comparison to small-scale model tests performed in the pressure tank. (note: the scope of work does not include the model testing)
- Use numerical model to evaluate representative *p-y* and *p-Q* curves.

Contact persons: Lars Bo Ibsen

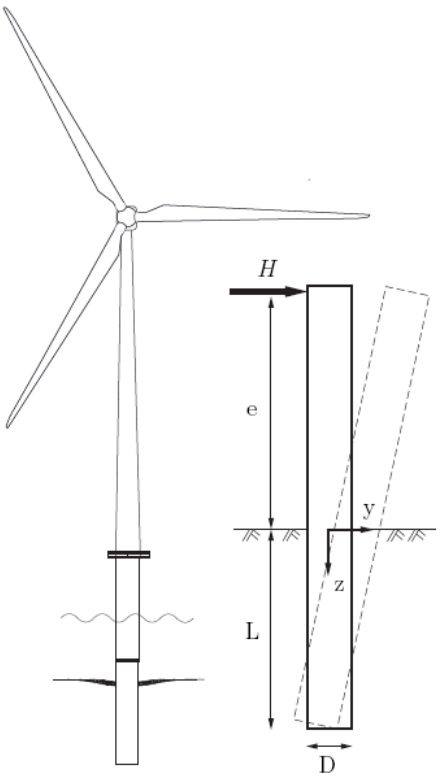
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Offshore Wind Turbine Foundations: Response of Stiff Piles to Long-term Cyclic Loading

A project in cooperation with

DONG energy

Purpose: There are several foundation concepts for offshore wind farms. Most current foundations are monopiles, which are stiff piles with large diameters, installed 20 m to 30 m into the seabed. The design of monopiles relies on standards and empirical data originating from the offshore oil and gas sector. However, the loading of an offshore wind turbine is very different in both magnitude and character to oil and gas installations. It is characteristic for offshore wind turbines that the sub-structure will be subjected to strong cyclic loading, originating from the wind and wave loads. This leads to accumulated rotation of the wind turbine tower, adversely affecting its ultimate strength or fatigue life. The long-term movements of the foundation may significantly impact all parts of the wind turbine, including the support structure, machine components and blades. Therefore, it is of great importance to investigate the effects of cyclic loading.



Series of laboratory tests shall be conducted using the pressure tank at AAU. The model tests must be conducted on a stiff pile installed in saturated sand and subjected to between 100 and 1000 cycles of combined moment and horizontal loading. A typical design for an offshore wind turbine monopile should be used as a basis for the study, to ensure that pile dimensions and loading ranges are realistic. A non-dimensional framework for stiff piles in sand must be applied to interpret the test results.

Main activities:

- A series of laboratory tests should be conducted on stiff piles in the pressure tank at AAU.
- Results should be used to develop methods assessing the change in stiffness and the accumulated rotation of a stiff pile due to long-term cyclic loading.

Contact persons: Lars Bo Ibsen

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

Load calculations on wind turbines – sensitivity study

Purpose: Wind turbines are designed for 20 years life time according to the design standard IEC 61400-1 ed. 3. This design standard specifies several standard wind turbine *design classes* with respect to wind speed and turbulence level. The standard also defines a list of *site parameters* to be estimated to describe the terrain and climate of a particular project location. Finally, the standard defines a number of particular *load cases* to be run, which cover normal and extreme operation.

A full aero-elastic load calculation may be performed for each of the standard *design classes* to obtain the total design loads on the main components. Similarly, load calculations may be performed for particular *site parameters*, and the loads may then be compared to those of the *design classes.* This allows evaluation of the *suitability* of a standard *design class* wind turbine for a particular site and set of *site parameters*.

The purpose of this project is to analyze the sensitivity of wind turbine load calculations and suitability evaluation to variations in each of the *site parameters?*

Main activities: The main project analysis requires the setup of a full load calculation basis according to IEC 61400-1 ed. 3 including the following components:

- An aero-elastic code like FAST/ADAMS, HAWC2 or FLEX5.
- An aero-elastic reference wind turbine model like the NREL 5MW model
- Specification of the relevant IEC 61400-1 ed. 3 load cases (extreme, etc.)
- ….

With this setup multiple load calculations must be run to analyze the sensitivity of the loads on the main components to variations in the *site parameters.*

The project involves co-operation with the external partner EMD International with special interest in evaluating site suitability of wind turbines related to site parameters. EMD hosts a computer cluster that may be used for the load calculations.

Contact persons: John Dalsgaard Sørensen & Henrik Stensgaard Toft
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒

Master Thesis projects in collaboration with DONG

The following list of master thesis projects is proposed by DONG. The projects can be found and applied through DONG's homepage until the 15. May 2012. A co-supervisor from DONG will be associated the projects.

1) Background for SN-curves for steel.

The objective of the project is to estimate SN-curves for steel details relevant for offshore wind turbines. The SN-curves in standards are expected to be conservative and normally estimated for other purposes than offshore wind turbines which typically have a lower reliability level than e.g. buildings.
(http://www.dongenergy.com/DA/Job/soeg%20job/Pages/Job_detail.aspx?jobid=110559)

2) Prediction of buckling limit of monopoles for offshore wind turbines.

The objective of the project is to estimate the buckling strength of monopiles which are exposed to a combined effect of moment, normal force, shear, torsion and lateral pressure. The buckling strength should be estimated using simple calculations, finite-element analysis and measurements. Especially the importance of imperfections is to be considered.
(http://www.dongenergy.com/DA/Job/soeg%20job/Pages/Job_detail.aspx?jobid=110743)

3) Distribution of uncertainties in wind resource assessment.

The objective of the project is to estimate the most appropriate distribution function for uncertainties related to wind resource assessment. These uncertainties are usually assumed normal distributed which not necessarily is the most appropriate distribution. The influence of using other distribution functions on the estimated power output should be investigated.
(http://www.dongenergy.com/DA/Job/soeg%20job/Pages/Job_detail.aspx?jobid=110549)

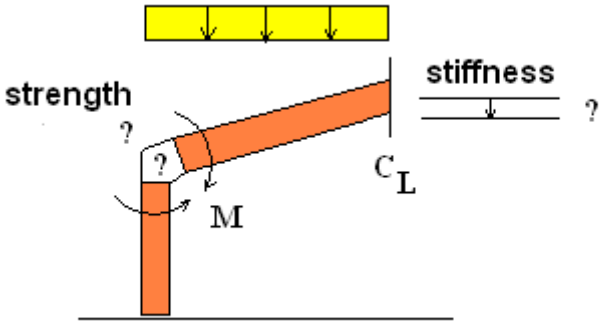
4) Fatigue of concrete in post-stressed wind turbine foundations.

The rules in the Eurocode for concrete structures are not adequate for fatigue design of the concrete in post-stressed structures as e.g. foundations for wind turbines. The objective of the project is to analyse and develop better methods for fatigue verifications for concrete in post-stressed foundations for wind turbines. This could include three-dimensional analysis of stress distributions, tests in lab, statistical analyses and reliability-based assessment of partial safety factors.

Contact person for these projects: DONG energy or Henrik Stensgaard Toft / John Dalsgaard Sørensen

The corner of laminated timber frames

Purpose: Laminated timber frames are, for instance, desirable in structures where the aesthetics of the structure is in focus. A weak point in a timber frame is the frame corner and its strength and stiffness. But perhaps the corner does not need be made of wood?



Could a reinforced concrete structure or a steel structure be employed in the corner instead? At least the drawbacks of a corner made of wood might be removed and by employing wood in the remaining part of the frame, the frame would still visually appear much like a full wooden frame.

Main activities: The aim of the project is to explore the stiffness and strength of a timber frame employing different solutions in the corner of the frame (steel and/or reinforced concrete and using the full timber frame as reference).

In the project you will develop numerical and analytical models for the various solutions and full-scale tests will be conducted aiming at verifying the strength and stiffness predicted by your models.

Should your investigations reveal that solutions with steel or reinforced concrete in the corner of the frame are feasible (in terms of strength and stiffness) it might indicate a potential for a new type of frame structures.

The project might involve co-operation with external parties having an interest in mapping the potential of alternative solutions for timber frames.

Contact persons: Lars Pedersen, Christian Frier

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Advanced Analysis of Steel Frames

Purpose: In ultimate limit state analyses of steel frames compression forces and bending moments are of concern, as they may lead to global instability manifested in either buckling or lateral torsion failure.

The design guide Eurocode sets up procedures for evaluating the ultimate limit state and actually Eurocode (EC) suggests a number of different design approaches to choose from. Some EC-approaches are more simplifying than others, and this means that the final evaluation of the ultimate limit state depends on the method chosen for the evaluation. Or does it?

The purpose of the study is to highlight and quantify load carrying capacity of steel frames employing different methods, ranging from basic methods to more advanced methods (in all methods FE-analyses are required but to various degree of complexity).

In the initial part of the study focus will be on analysing a reference steel frame, but in order to highlight the degree of differences in calculated load carrying capacities it is useful to extend the study. This, for instance, by studying a range of steel frame configurations or to conduct some other type of parameter study focusing on sensitivity of outcome of your calculations to input assumptions related to structural modelling.

Main activities: Besides from a literature review focusing on the background for EC-guidance focus will be on

- Implementing and describing procedures
- Finite element modelling and analyses
- Parameter and sensitivity studies

so as to provide an overview of load carrying capacities of steel frames as computed using different methods.

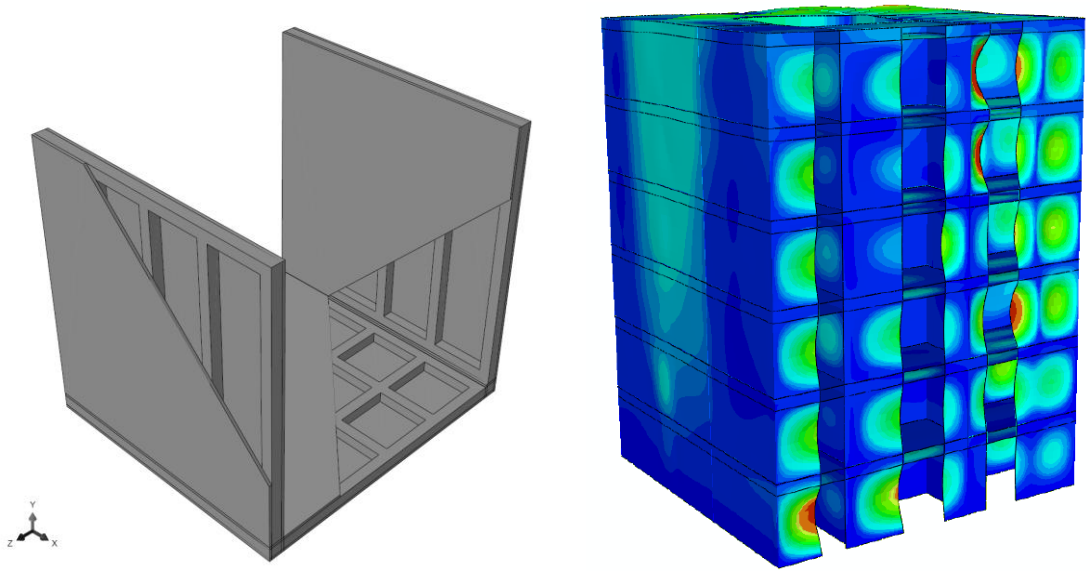
As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen, Johan Clausen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

Noise and vibrations in lightweight building structures

Purpose: Walls and floors in lightweight timber structures are usually constructed as wooden panels. Depending on the geometry, material properties and boundary conditions, such panels may resonate at different frequencies within the audible range, leading to emission of noise. Furthermore, the panels may serve as waveguides, transmitting noise from one room to another or between floors. The project may concentrate on a global model for a building—or transmission paths may be studied at a local level, e.g. at a junction between a wall and a floor. Alternatively, the project may focus on an optimized design of wall or floor panels where the studs or joists are placed periodically to minimize noise transmission in the audible range.



Main activities: The project is relatively open with concern to the problem to be analysed. The activities may include:

- Literature study of building acoustics
- Formulation of models for dynamic analysis of periodic structures
- Design of joints in building structures for mitigation of noise
- Parameter studies to identify the influence of geometry and material properties on sound transmission in lightweight building structures
- Finite-element modelling of coupled acoustics and structural vibration
- Experimental testing of structural dynamics and acoustics.

Contact person: Lars Andersen & Poul Henning Kirkegaard

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

Finite-element modelling of reinforced concrete

Purpose: Reinforced concrete is widely applied as a construction material in civil engineering. Concrete is a complex material, both chemically and mechanically, and the formulation of material models demands a deep knowledge of the behaviour during casting, curing, utilization and, eventually, degradation. The introduction of reinforcement results in a composite material. In this case the interaction between the concrete matrix and the steel reinforcement must be accounted for as well.



The idea in this project is to use advanced finite element calculations, e.g. via ABAQUS, to model reinforced concrete. Different methods should be compared, and a comparison with analytical methods should also be included. The project may focus on the analysis of a particular problem or structure.

Main activities:

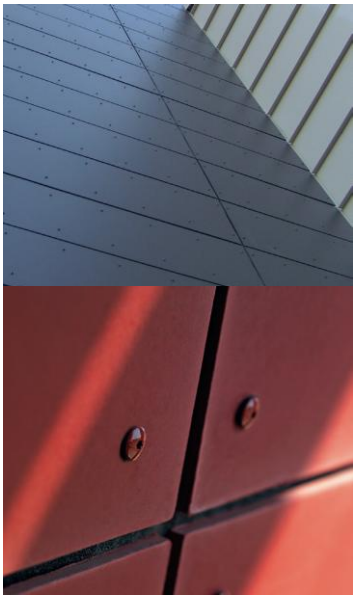
- Formulation of material models for concrete. This can be both built-in models in Abaqus and user supplied models.
- Modelling of interfaces between concrete and reinforcement
- Finite-element analysis of reinforced concrete structures
- Comparison of FE models with standard design methods.

Contact person: Johan Clausen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

Carbon dioxide curing of fibre-cement materials

Purpose: The objective of the proposed project is to establish a method for hardening fibre-cement materials in a carbon dioxide atmosphere and to determine the main properties of the hardened products as compared to air cured materials.



Background: Fibre-cement is a cement based fibre reinforced composite which is widely used throughout the world for a number of applications, notably lightweight roofing and cladding. One of the largest European producers of fibre-cement is the Cembrit Group with headquarters and R&D centre located in Aalborg.
Fibre-cement is composed of cement, microsilica, inorganic fillers, and natural and synthetic fibres, and is produced through a highly specialized process. Currently the materials are hardened by simple air curing. It has been found that the rate of hardening may be significantly enhanced by curing the materials in a concentrated carbon dioxide atmosphere. It is also known that such hardening will produce a different microstructure of the hardened material as compared to air curing. As a consequence, the properties of the final products, e.g. moisture induced shrinkage and swelling, resistance against freezing/thawing attack, and strength and stiffness, will be affected.
The proposed production method is environmentally friendly since carbon dioxide is consumed in the curing process.

Main activities: The project is relatively open concerning the specific approach to the subject. However, in any case the activities will include:

- Getting to know fibre-cement products and production
- Literature review of carbon dioxide curing of cement based materials.
- Design and set-up of carbon dioxide curing facilities at a laboratory scale
- Preparation and curing of specimens and measurement of properties as a function of curing method.
- Discussion of results in relation to theory.
- Recommendation of production method based on carbon dioxide curing.

The project will be carried out in close cooperation with the R&D department of Cembrit.

Contact person: Eigil V. Sørensen.

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

Compositon and properties of fibre-cement materials

Purpose: The objective of the proposed project is to provide a basis for optimization of mechanical and durability properties of fibre-cement materials by varying the nature of the components and the mix design of the material.

Background: Fibre-cement is a cement based fibre reinforced composite which is widely used throughout the world for a number of applications, notably lightweight roofing and cladding. One of the largest European producers of fibre-cement is the Cembrit Group with headquarters and R&D centre located in Aalborg.

Fibre-cement is composed of cement, microsilica, inorganic fillers, and natural and synthetic fibres, and is produced through a highly specialized process. Various characteristics of the material, such as moisture induced shrinkage and swelling, and resistance against freezing/thawing attack, in addition to mechanical properties such as strength and stiffness, are important to secure the proper functioning and adequate service life of the products. These characteristics depend on the nature of the microstructure of the material which in turn can be manipulated through the type and relative amounts of the constituent materials in the mix design.

Main activities: The project is relatively open concerning the specific approach to the subject. However, in any case the activities will include:

- Getting to know fibre-cement products and production
- Identification of focus areas based on literature review and theoretical considerations
- Preparation of specimens and measurement of properties as a function of composition variations, at the AAU Concrete Laboratory and at Cembrit's laboratories.
- Discussion of results in relation to theory.
- Recommendation of optimization options.

The project will be carried out in close cooperation with the R&D department of Cembrit.

Contact person: Eigil V. Sørensen.

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

Precast post tensioned CRC footbridge

Purpose: The objective of the proposed project is to theoretically, numerically and experimentally analyse and optimize post tensioning assemblage of a footbridge based on precast units of ultra high performance concrete.

Background: CRC (Compact Reinforced Composite) is an ultra high performance fibre reinforced concrete consisting of a dense and high strength cement based matrix with steel fibres added to achieve ductility, and with ordinary steel bars as the main reinforcement. Specialized prefabricated CRC units are produced for a wide range of applications by the company Hi-Con A/S in Hjallerup.

For many applications it would be advantageous to assemble precast CRC units in situ by post tensioning to construct long or tall structures. The proposed project will focus on a light and slender footbridge for urban areas. The wall thickness of the units, and thereby the maximum size of the anchorage zone for the tendons, is relatively small in order to minimize the dead weight of the bridge. However, due to the high strength and the ductility of CRC as compared to traditional concrete the forces can be carried by a smaller anchorage region, and it may even be expected that both the anchorage reinforcement and the reinforcement for the splitting tensile stresses generated by the concentrated loads are smaller than known from traditional concrete.

Main activities: The project is relatively open concerning the specific approach to the subject. However, in any case the activities will include:

- Getting to know ultra high performance fibre reinforced concrete (CRC), including potential applications and production and construction of CRC based structures
- By reference to the design of traditional post tensioned concrete structures analyse possibilities for simplifications of the anchorage zone reinforcement and enhancement of the overall performance of a footbridge constructed with precast CRC units, utilizing the special features of CRC.
- FEM-based computations and simulations
- Experimental investigations and validations of the calculations by testing specially produced and designed CRC units

The project will be carried out in close cooperation with Hi-Con A/S.

Contact persons: Lars Pedersen and Eigil V. Sørensen.

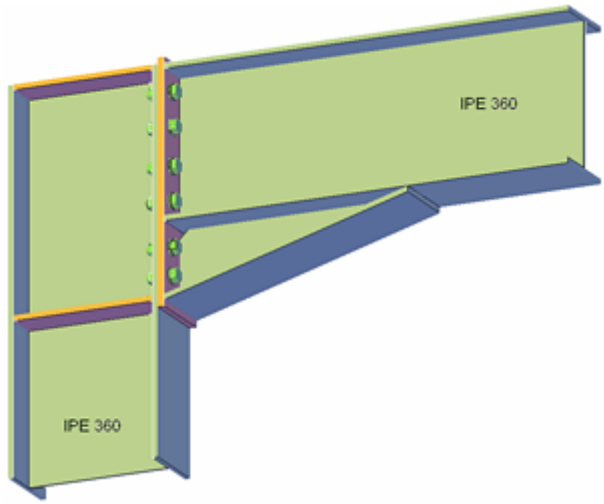
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Analysis of Joints in Steel Structures

Purpose: Joints in steel structures are frequently made using fasteners. These are not fully rigid which may play a role in terms of behaviour of the steel frame.

The purpose of the project is to investigate how flexibility in joints influences various global characteristics of the steel frame, and to study how Eurocode models these influences.

Another item of interest is to explore the load bearing capacity of joints made using fasteners (analytically, numerically, and experimentally) and to compare results with Eurocode models.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

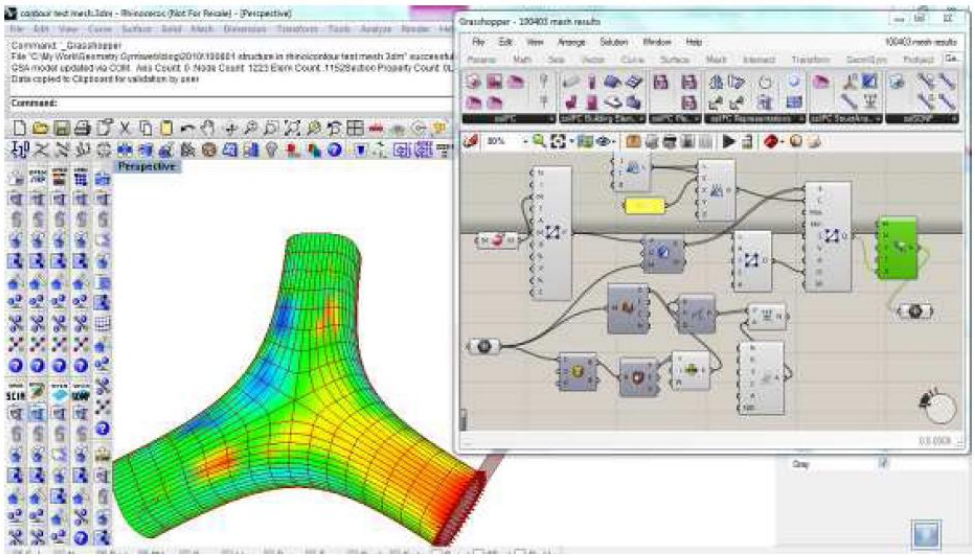
- A mixture of analytical, numerical and experimental investigations
- Comparison of results with Eurocode models.

Contact persons: Lars Pedersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

Integrated Geometry Modelling, FEA and Parametric Structural Design of Civil Engineering Structures

Purpose: During the last decades design of structures has been through a transformation from manually driven tool-based design to digitally driven form-based design (form finding). For example, the output of a computer-aided geometric design system is typically not suitable as direct input for a Finite Element Analysis (FEA). This is usually addressed through intermediate tools such as mesh generators. Unfortunately, these are notoriously lacking in robustness. Even once a geometric model has been successfully meshed, the output of a FEA cannot be directly applied to the original geometric model, since there is no straightforward mapping back to the original design degrees of freedom. The present project will look into the development of computational methods for form finding, optimization and production of complex geometry for civil engineering structures and a Python based toolbox which can support parametric modelling will be developed



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

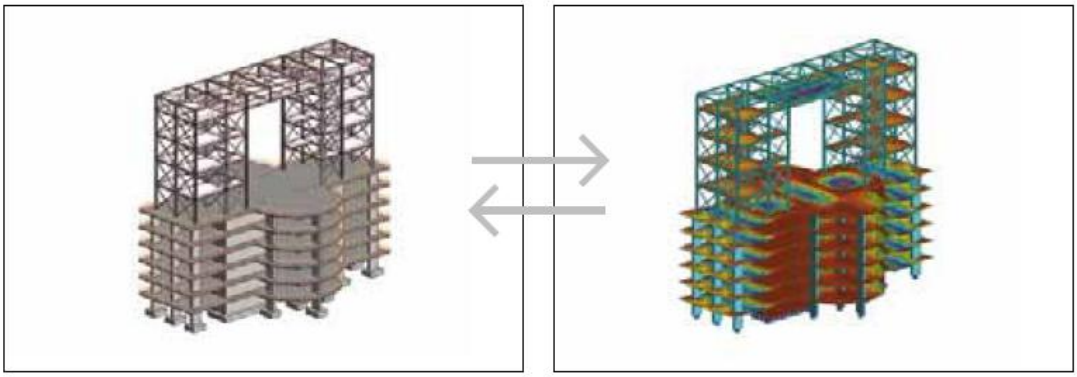
- Getting to know methodologies for form finding
- Determination of focus areas
- Theoretical and numerical FEA
- Development a Python based toolbox for the integration of CAD and FEA tools

Contact persons: Poul Henning Kirkegaard, Dario Parigi

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

Structural modelling and analysis using BIM tools

Purpose: Although 2D and 3D modeling software has been used for decades to analyze and design structures, over the past few years a wave of new 3D modeling tools are allowing structural engineers and designers to create models for documentation and coordination as well. As a result, more and more structural engineering firms are embracing the Building Information Modeling (BIM) movement. BIM software is based on the object-oriented programming paradigm, in which instances of structural members are assembled to create a building structure. Each member possesses the information and functionality that fully defines it. In other words, a beam element knows its properties (e.g. material, sectional properties…), as well as its purpose within the structure (i.e. a horizontal member on level X, spanning between column Y and girder Z). The resulting BIM model contains a wealth of information which can be useful for inter-discipline coordination as well as internal coordination. Recently many add-on BIM tools have been presented which integrated the structural analysis of e.g. reinfored concrete and steel structures into the BIM framework.
The purpose of the present project is to perform an evaluation of add-on tools for structural analysis.



Main activities:

- Identify strength and limitations in current add-on BIM tools and identify opportunities with upcoming technologies in the area
- Modelling and structural analysis of different structures and comparison with theory and traditional FEM results.

The work may be in collaboration with RAMBØLL.

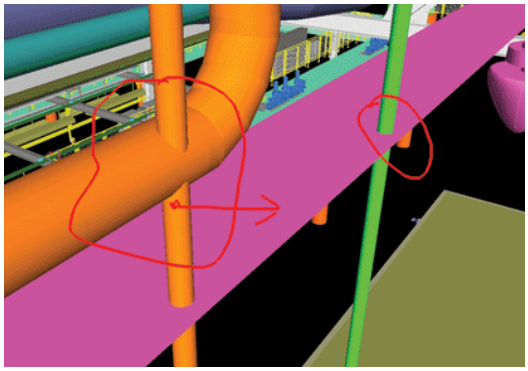
Contact person: Poul Henning Kirkegaard

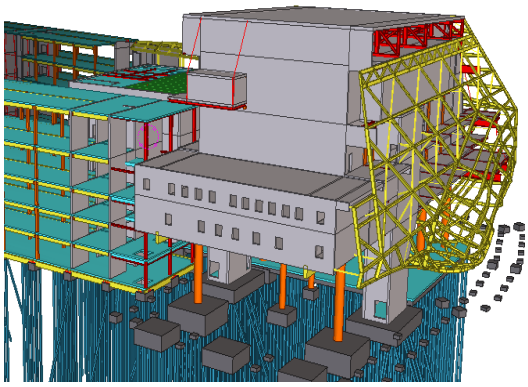
Theory: ☒☒☐ **Experimental Work:** ☐☐☐ **Computer Modelling:** ☒☒☒

Structural modelling and design coordination

Purpose: The construction industry is changing from traditional CAD drawings to more intelligent 3D object based models of the entire building. There are many attempts to improve the structural design process by making a better connection between object based CAD systems and structural simulation tools. The simulation tools can be more or less integrated with specific CAD systems or they may exchange data through open international standards. An important issue for the structural engineer is also the often complicated coordination with requirements from other disciplines such as architecture, HVAC etc. New IT tools are introduced to assist this coordination.

The purpose of this project is to identify critical elements of the integrated design and coordination process and examine how new methods and information technology can assist us in the future construction industry.





Main activities:

- Identify strength and limitations in current practices and identify opportunities with upcoming technologies in the area
- Review of enabling Information and Communication technologies (ICT), including software, data models, international standards, and human computer interaction tools
- Examine today's possibilities with existing tools
- Identify needs for new ways of working and from that derive a list of requirements on technical solutions
- Demonstrate possible solutions for the near future and describe issues for future development

The work may be in collaboration with a consulting engineering company.

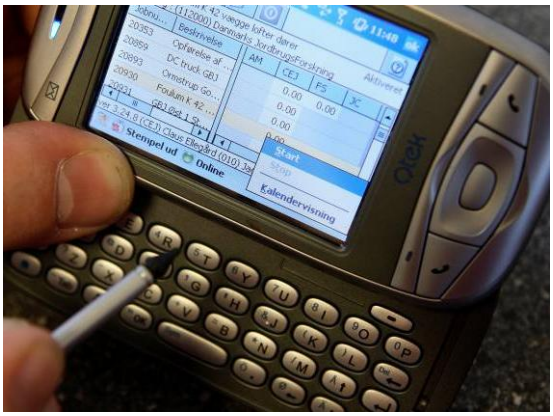
Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Future information technology at the construction site

Purpose: In recent years, the construction industry has started changing from traditional 2D CAD drawings to more intelligent 3D object based models of the entire building. Such models give us a number of new possibilities for planning and controlling the activities at the construction site through advanced 4D models and possible links between the physical construction components and the virtual building model. New information and communication technology can improve the communication of correct instructions at the right time for the construction work as well as capturing information for quality assurance and as-built documentation.

The purpose of this project is to identify important problems within the area and propose solutions for future use of state-of-the-art information technology at the construction site.



Main activities:

- Identify current practices and problems in traditional construction projects
- Review of enabling technologies, software, hardware, international initiatives
- Test existing methods, software, hardware
- Identify needs and requirements for new solutions
- Build early prototypes with more or less functionality for initial tests

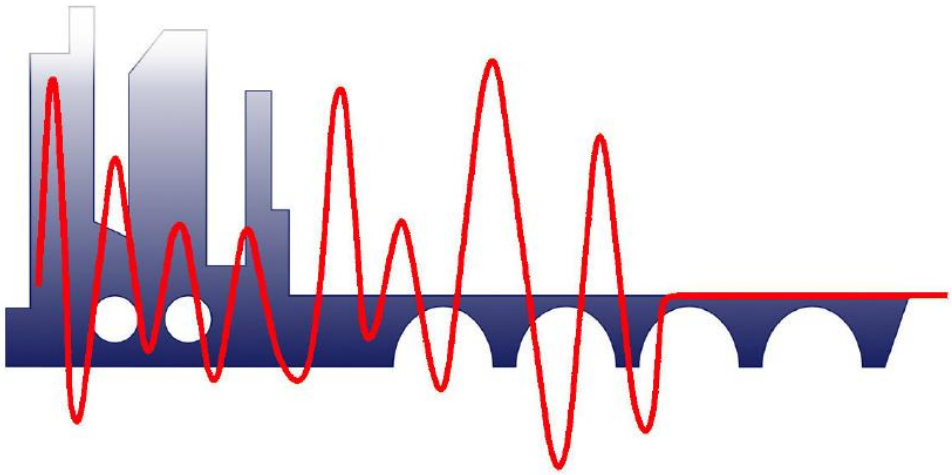
The work may be carried out in collaboration with a construction company.

Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Applied System Identification for Analysis of Non-Linear Phenomena in Civil Engineering Structures.

Purpose: In literature the analysis of nonlinear and time-varying systems are often treated separately. The nonlinear systems are identified with specific tools and the time-varying systems are usually analyzed with parametric methods or techniques extended from the linear time-invariant case. The present project will look into experimental system identification methods for time-varying and nonlinear cases, e.g. the `frozen technique' which can establish the time-frequency relationship of modal parameters. Many interesting time-varying problems can generate non-linear phenomena related to civil engineering structures, especially offshore structures. However, concrete bridges subjected to time-variability in a load from e.g. a train/vehicle can also have a non-linear softening behavior.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- Getting to know system identification methods for Civil Engineering Structures
- Theoretical and experimental evaluation of system identification methods
- Determination of focus areas
- One or two civil engineering problems dealing with non-linear phenomena will be analysed using theory, experimental work and computer modelling

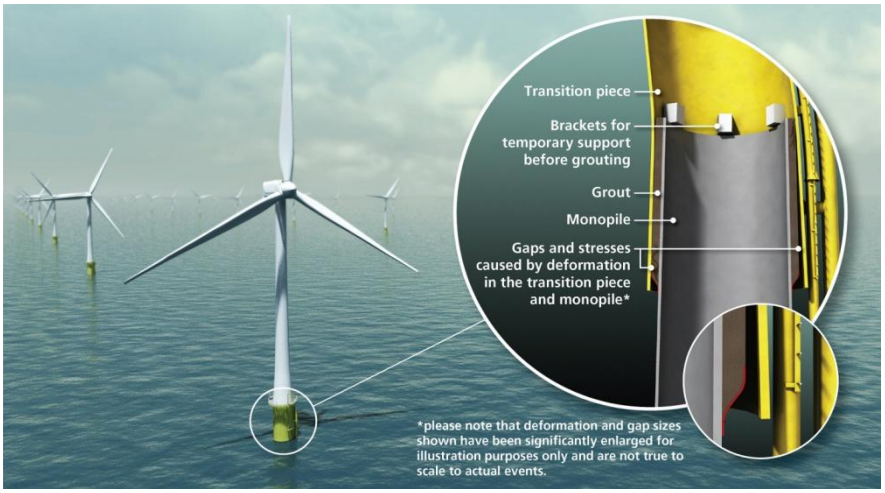
Part of the project can be carried out together with Rambøll - Esbjerg on experimental data measured at civil engineering structures.

Contact persons: Poul Henning Kirkegaard, Lars Damkilde

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

Structural Health Monitoring of Grouted Foundation Part for Offshore Wind Turbines

Purpose: The grout connection ties a mono-pile foundation to the tower on an offshore wind turbine. More or less all offshore wind turbines on mono-piles have this structural solution. Unfortunately, vertical settlements have been observed due to loss of friction/bonding in the grout material. This observation obviously requires a reassessment of the structural integrity of the grout connection. However visual inspections are not possible and as such calibration of a detailed FE Model is practically impossible. However, using FE Models representing different assumed stages in the failure propagation process of the grout connection in combination with a method for analysing the frequency content of acceleration measurements from the tower top of the wind turbine - an indicator signal representing the fatigue degradation level of the connection may be constructed.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- Getting to know structural health monitoring methods and grouted connections
- Determination of focus areas
- Theoretical, numerical (FEA) and experimental evaluation of grouted connection and failure mode identification
- Development of an indicator signal representing the fatigue degradation level

Part of the project can be carried out together with LAC engineering (www.lacengineering.com) on experimental data measured at operating offshore wind turbines

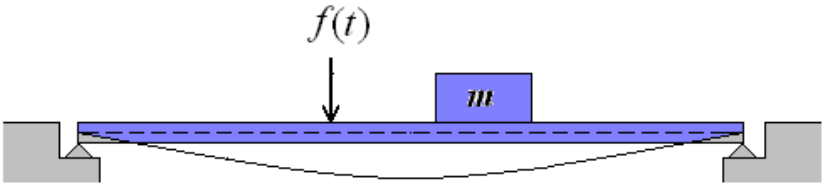
Contact persons: Poul Henning Kirkegaard

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

Dynamic human-structure interaction

Background: In static calculus, passive (sitting/standing) humans are modelled as a rigid mass attached to the structure. In dynamics, humans in motion (people walking or jumping) are modelled as a dynamic load bringing the supporting structure into vibration.

Human in motion Passive person



In assessments of vibration levels of slender structures carrying humans (such as footbridges, stadia-structures, or office floors) these models are conventionally employed. But are they reasonable?

Purpose: The aim of the project is to study mechanisms of human-structure interaction focusing on areas where the models mentioned above are inadequate. Prior to codifying new models describing the phenomena, they need to be properly researched.

In the project you will plan and conduct experiments striving to highlight the true mechanisms of human-structure interaction on slender structures. Measured vibration data will allow you to calibrate alternative models of the interaction accounting for the flaws in existing models.

Implications of findings (new models of the interaction) you may illustrate through computer simulations of structural response to the dynamic loads generated by humans.

Contact person: Lars Pedersen

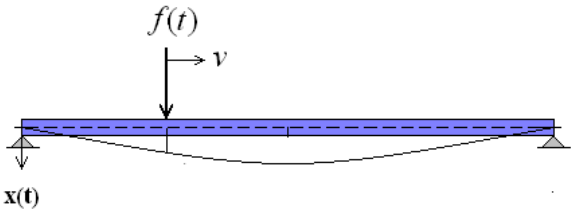
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Dynamic human loading and stochastic models for estimating structural responses

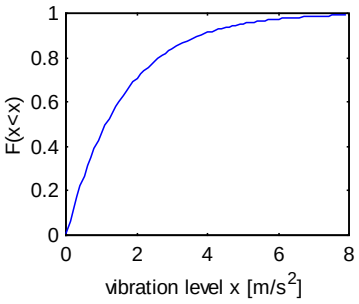
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result of walking or jumping.

Codes and standards handle the phenomenon semi-empirically or even fully deterministic although fundamentally the loading generated by humans in motion is stochastic.

Purpose: The aim of the project is to develop and test stochastic models describing the loading and the structural response. An essential contribution would be to derive statistical distributions of structural responses to human-induced loading, as this would provide valuable information for assessing structural safety or serviceability. Specifically, the risk of exceeding various vibration levels is of interest although it is actually a parameter not given much/any focus in existing design codes.



Walking load when v > 0 m/s, ”Jumping load ” when v = 0 m/s



Statistical distribution of response

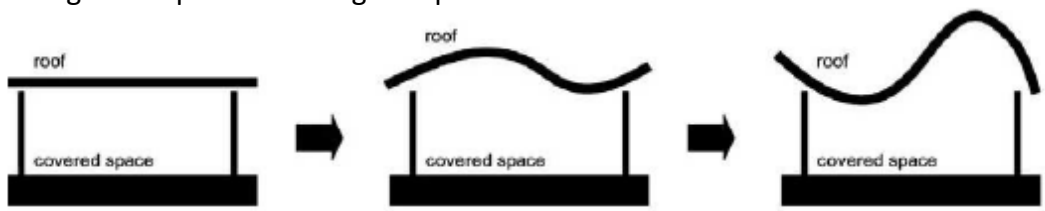
Through the project you will learn how to model the dynamic excitation of humans in motion, deterministically as well as stochastically. You will conduct parametric studies and numerical simulations to highlight essential implications of stochastic modelling of the phenomenon. Experimental verification of models is a possibility if so desired.

Contact persons: Lars Pedersen, Christian Frier

Theory: ☒☐☐ **Experimental works:** ☐☐☐ **Computer modelling:** ☒☒☒
(The amount of experimental work can be decided during the project)

MBS modelling of kinetic structures

Purpose: Kinetic structures follows a new trend emerging in architecture related to the physical movement of structural building elements that can result to the spatial movement of a structure as an entirety or just part of it. More particularly, this kind of architecture can be defined as: Buildings and/or building components with variable mobility, location and/or geometry. Structural solutions must be considered in parallel both the *ways* and *means* for kinetic operability. The *ways* in which a kinetic structural solution performs may include among others, folding, sliding, expanding, and transforming in both size and shape. Shape control within architectural kinetic structures is a natural extension to the practice of engineering and architectural design. Structural shape control is of major interest within responsive architecture because it is the primary ingredient needed to produce building envelopes that change shape.



Developing of responsive kinetic architecture requires that one could simulate such a mechatonic system as a multibody system (MBS) combined with a shape control method.

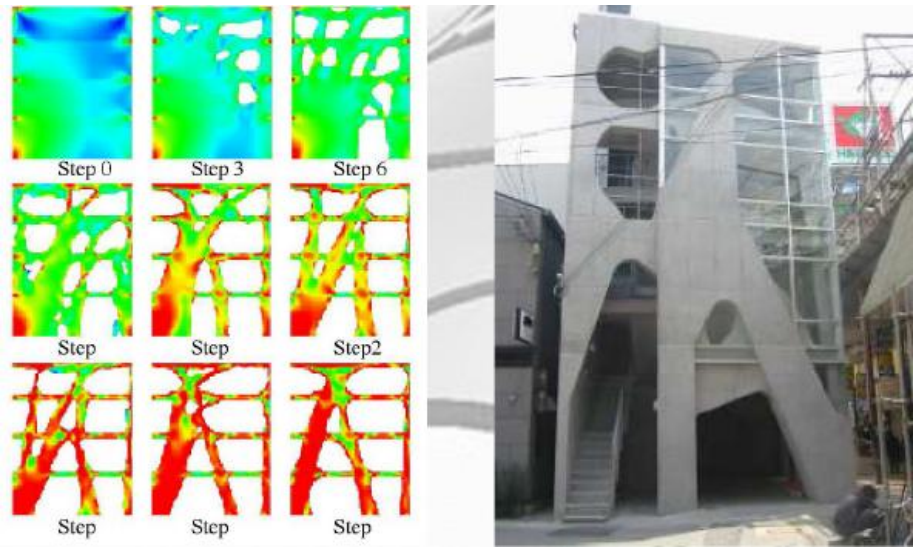
Main activities: The project will be related to ongoing research at the university where the MBS method is used related to wind turbines and kinetic structures. The main activities in the project will be:

- Getting to know the MBS method (FEM method)
- Getting to know shape control methods
- MBS modelling of a kinetic structure using the software packages ADAMS and Simulink.

Contact persons: Poul Henning Kirkegaard, Søren R.K. Nielsen

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Structural Design using Structural Optimization



Purpose: In the last few years a number of computational methods have been developed for structural optimization, methods for structural shape optimizationor for topology optimization like evolutionary structural optimization methods (ESO / Extended ESO). Most of these methods are based on dissecting the element into numerous parts for the optimization process and by deleting or adding parts after individually being tested against the design objective, which is achieved by variation of the design variables who are subjected to the design constraints in a process of multiple iterations. Over the past two decades there has been an increasing interest in using what has come to be called Evolutionary Computation (EC) in the analysis and optimization of structural systems. These methods include Genetic Algorithms (GA), Evolution Strategies (ES), Simulated Annealing and other stochastic based numerical methods. Each of these methods shares the drawback that they are very computationally intensive compared to deterministic methods. Furthermore, the computational burden can rapidly increase as the size of the analyzed structure increases. This project will consider how shape and topology optimization methods can be used for structural design.

Main activities:

- Knowledge of shape an topology optimization methods in civil engineering
- Evaluating the FEM program OptiStruct
- Comparative case studies evaluating a broader range of good solutions

Contact person: Poul Henning Kirkegaard, Lars Andersen

Theory: ☒☒☐ **Experimental Work:** ☐☐☐ **Computer Modelling:** ☒☒☒

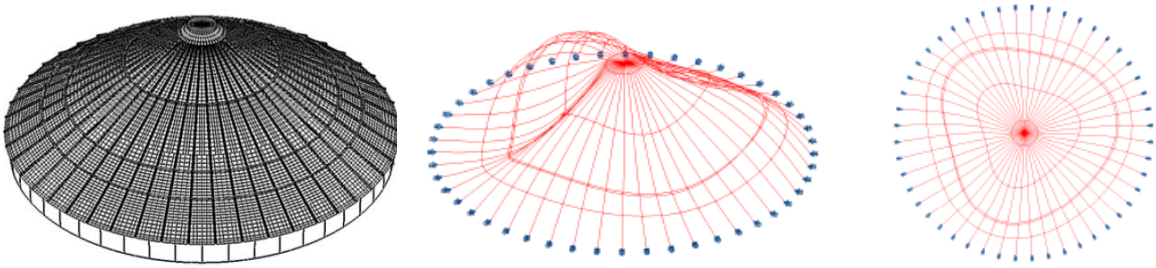
Example of company stay project

Analysis of snow-load induced damage on conical silo roof

Company: Cowi, Aalborg Office
Company type: Consulting engineering company
Webpage: www.cowi.dk, www.cowi.com
Location: Aalborg

In the winter of 2009/2010 heavy snowfalls occured in Northern Jutland in Denmark. The ensuing large snowloads caused several roof collapses throughout the region. Among these were the several roofs of silos for crop storage. Crop silo structures are typically composed of corrugated steel sheets stiffened by steel profiles.

The company wanted to perform a detailed analysis of these collapses to assess the cause(s), and this was chosen as a project for the student doing the company stay.



The structure was studied by means of finite element analysis, including non-linear effects such as bifurcation buckling, large displacements and plasticity. Also, different detail levels in the modelling were compared, as was beam and shell models.

ISSN 1901-7308
DCE Latest News No. 31